Understanding ourselves and the environment in which we live

Journal Item

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Abstract

This paper calls for a new methodological paradigm for understanding the adaptive human-nature relationship to achieve a sustainable global environment. It proposes three future research directions: theoretically framing societal processes in natural resources management; establishing a new methodological paradigm for understanding co-evolving human-nature systems; and developing system-scale experimental research.

EXPRESSING the NEED: for further understanding the dynamics of the human nature system for a sustainable global environment

The sun, earth, moon, plants, animals, other biota and ourselves all together form a splendid world. For a long time human society has been at one end of this spectrum and the natural world at the other end. The harmonious interaction between humans and nature presents a beautiful picture. From ancient philosophy, to scientific philosophy, then to modern science, natural systems and societal systems have belonged to two different domains of understanding and practice in the sciences. The natural and social sciences have developed with different objects, methods and paradigms [1][1]. The object of natural science is considered to be context-independent; it is therefore possible that problems can be structured with mathematical equations. In contrast, the object of social science is to abstract context-free features from context-dependent human activities [2]. Many, if not most, situations of concern can be characterized as unstructured or wicked problems that are difficult to formalize.

Generally speaking, quantitative approaches and qualitative approaches are used by natural science and social science respectively. The underlying idea, or prejudice, is that the former

[1] Formulated in 1959, the two cultures have not gone away – see https://www.telegraph.co.uk/technology/5273453/Fifty-years-on-CP-Snows-Two-Cultures-are-united-in-desperation.html

is objective, whereas the latter is subjective [3••]. Finally, natural scientists are mainly interested in, with numerical models, predicting or projecting what happens in future populations. In contrast, social scientists, using descriptive models, analyse the relationships in past populations, providing “postdictive” statements [4,5]. It is commonly held that there is an insurmountable gap between natural science and social science.

Recently, humans have begun to notice that their activities have significantly modified the earth's biosphere and thus disturbed the environment in which they live. This has led to calls for the proclamation of a new geological age - the Anthropocene [6,7]. Land desertification, drying of rivers, disappearance of wetlands, climate change, pollution and biodiversity loss have contributed to a loss of the ‘emergent splendor’ arising from the interactions between humans and nature. The learning that emerges from understanding the ‘Anthropocene phenomena’, learning that both global society and science struggle to come to terms with, is that human society and the natural world are best understood as a ‘coupled, co-evolving system’. The practices of natural science and social science have to be integrated to understand and govern this co-evolving human-nature system.

Many multiple-disciplinary, cross-disciplinary and inter-disciplinary studies on environmental science and management have been contributing to bridging the gulf between natural science and social science for the last several decades. This issue, entitled “*System Dynamics and Sustainability*” contributes to furthering our understanding of the challenges that arise when attempting integration of natural science and social science in the field of global environmental change. It particularly focuses on advances in understanding of the interactions between the change in biophysical processes and change in the societal processes over a long timeframe.

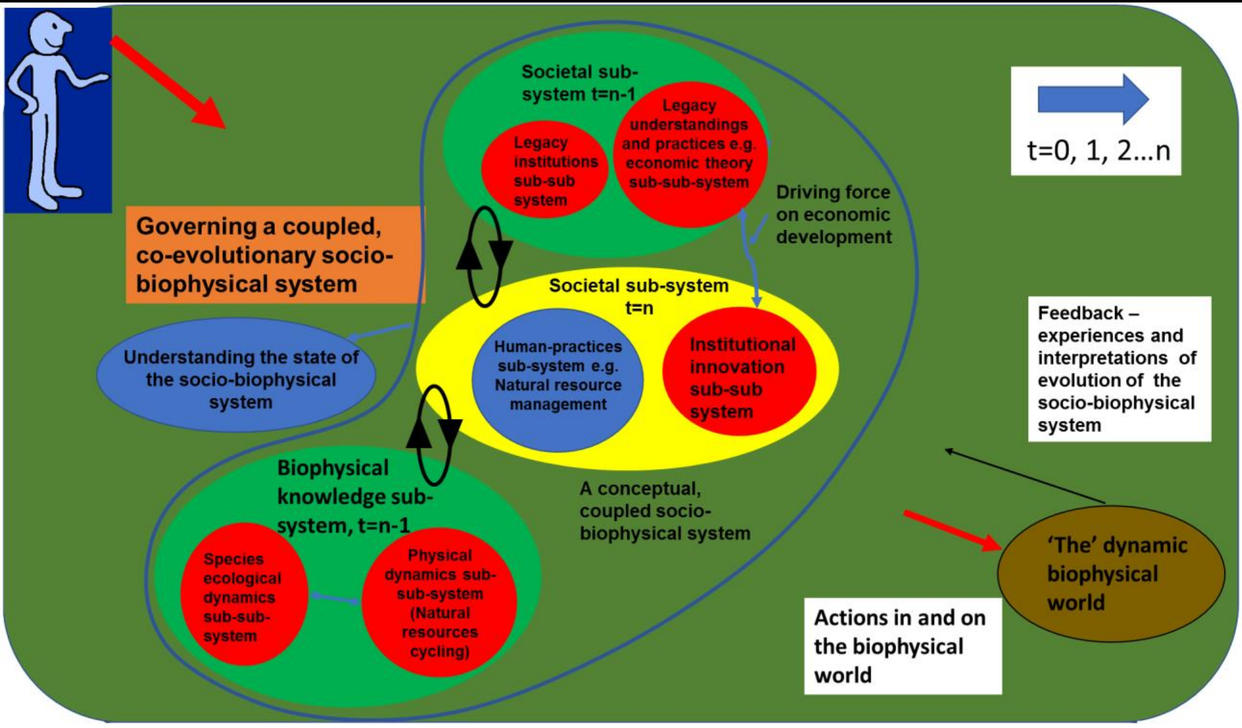
This issue comprises 19 papers, presenting progress reviews, theoretical research and empirical studies in relation to interactive processes of global environment change. It covers several themes including structure, function and services of ecosystems, hydrology and catchment management, and land and soil conservation. Several new frameworks are presented. These offer valuable insights into particular sub-systems (e.g. water, land), processes, (e.g. ecological, hydrological), phenomena (e.g. spillover effect) or a management issue (e.g. water allocation, soil conservation); others make the case for the development of more generic frameworks for addressing the general human-nature relationship . The latter are needed for addressing contemporary global environmental problems when answering the question of how things should be, explaining how things are and why things are the way they are. Therefore, we suggest the following three research directions for advancing our understanding of the unfolding human-nature relationship.

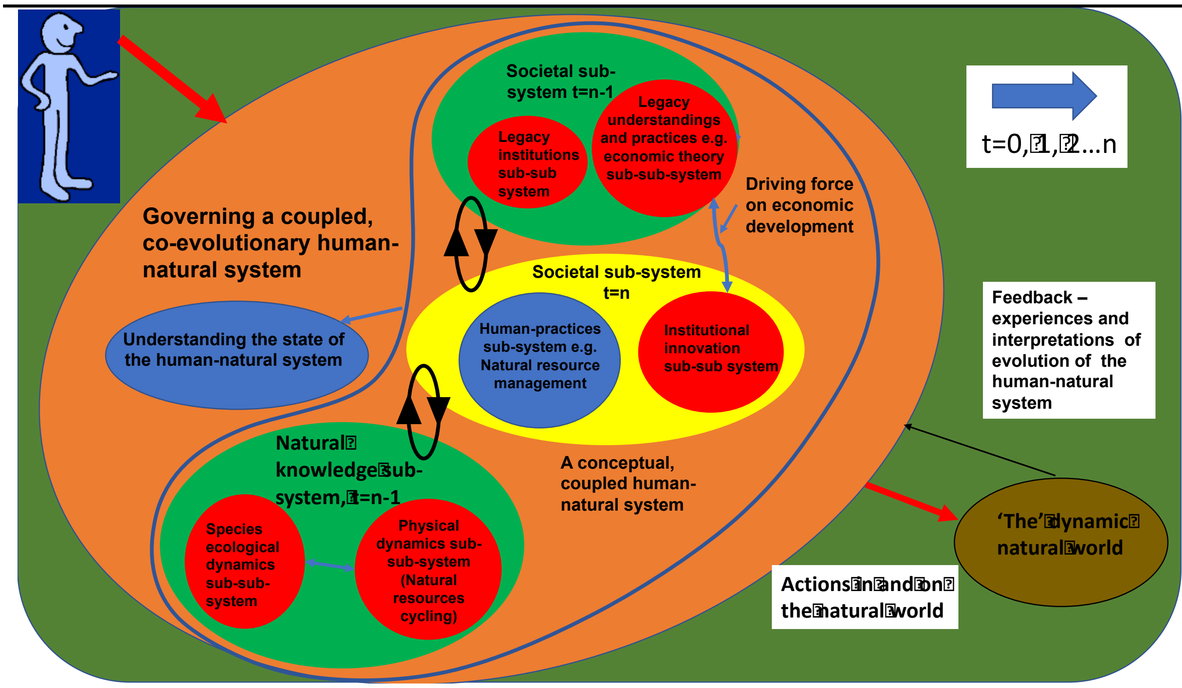
THEORETICALLY FRAMING societal processes

We have recognized that human activities have significantly modified the Earth's surface. However, as there exist lags in the two-way feedbacks between the natural system and human system and there is limited understanding of transitions between multiple equilibrium states of these systems, the mechanisms of influence of human activities on the natural system over long timeframes are not clear. The great challenge is to improve the feedback between changes in critical natural processes and human (re)action, both in terms of reducing lag and ensuring sufficiently strong feedback to stabilize the coupled systems. Science produces scientific explanations for phenomena; but acceptance, or otherwise, of these explanations and processes of interpretation sit squarely within the societal system. With either a lag in scientific understanding and/or a lag in effective human action, natural resources management decisions can never be taken in a timely and wise way. We argue that this is the direct cause of an unsustainable global environment.

We propose a conceptual framework for understanding the mechanism of influence of human activities (a societal system) in relation to natural system (Figure 1). The figure is constructed so as to highlight that the human societal system is central to a co-evolutionary future in which humans play a part. The natural system including other species and physical processes can continue in the absence of humans, although we already know that human impact will continue to shape these dynamics for some time and create ‘legacy systems’. The key question is, what will the quality of human life be into the future and what are our ethical responsibilities in relation to other life?

Figure 1





A heuristic device to foster exploration of the dynamics of a human societal system which has to be governed, co-evolving with a natural biophysical world, which for the moment has humans who are capable of effecting whole earth dynamics.

Figure 1 is a heuristic device; a conceptual picture designed to facilitate thinking and conversing about how we humans understand and reshape the environments where we live. This is not a picture of how the world is. But it could be used as part of a process to help us, and the world, do things differently. Figure 1 can be read by starting at the yellow societal sub-system at time t=n. Within this subsystem we highlight two sub-sub-systems: the first is concerned with human practices – what people do when they do what they do [8,9], e.g. natural resources management. The other is concerned with human invention of institutions (norms and rules of the game which operate in all social groups and human invented technologies [10]). There are legacy systems operating now; sometimes we are aware of this, sometimes not (11••,12••,13). Two legacy sub-systems are presented in Figure 1 (two green parts). The first is the historical human invention of institutions; and the second is the understandings, explanations we accept or reject from experiences and study of the natural world. The societal sub-system and two legacy sub-systems are our understanding of the state of the human-nature system (blue part), which mediate, or facilitate human activities and impact on the natural system (brown part in the right of Figure 1).

There are two important lags in observation, explanation and societal action. The first lag is in understanding; this is due to the current understanding being based on past data. In fact, even when using real-time data, our knowledge must still lag as trends and changes emerge slowly and knowledge takes time to mature – we prefer it to stand the test of time. The second lag is in response due to decision making, which involves debate, and development and implementation of policy and action plans. We try to address the second by using future scenarios but that is only partially effective for many socio-political and economic reasons, as well as the inertia in our physical, human and other capitals. Uncertainty is an important issue in slowing response and future scenarios are of course limited by the lag in knowledge.

As discussed above, the limited scientific understanding of state transitions of these co-evolutionary human-nature systems and, in particular, the poorly developed ability of our institutional arrangements and governing system to interpret and extrapolate from expected patterns and trends and to decide on desired future states [9] have led to the attenuation of feedback (lags) and very slow speed of human (re)action (the slender arrow in right part of Figure 1). To address this, we think there is an urgent need for a new methodological paradigm for understanding ourselves and the environment in which we live.

ESTABLISH a new methodological paradigm

Since the dawn of their existence, humans have developed different explanatory systems based on our observation and understanding of the part(s) of the co-evolving human-nature system where we live. Physical sciences such as hydrology and other natural resource disciplines follow Newtonian traditions. They are based on energy and mass balance using the continuity equation, and tend to a mechanistic understanding often aiming for universality, simplicity, and predictability; although that is tempered by examples of complex and chaotic systems with limited predictability, such as the weather. Ecology and other biological sciences follow Darwinian traditions emphasizing selection and evolution as the main drivers of system evolution, which is characterized with contingency and self-organization [14••]. There are many philosophical schools considering the human societal system, in which the most representative ones are historical materialism and dialectical materialism, characterized by relativity (the historical and comparative perspectives) and specificity (varying with different cases). The development of knowledge in understanding global environmental issues in past decades was largely based on these three individual philosophical methodologies operating independently, but the world where the sun, earth, moon, plants, animals and ourselves exist is best understood as a co-evolving human-nature system. It makes little sense to treat each sub-system separately and we argue that this is an important cause of global environmental degradation.

Scientists across sociology, economics, ecology, hydrology, biology, and other disciplines have called repeatedly for greater integration between natural science and social science [15-19]. Typically, these calls explain why such research is needed accompanied by illustrative case studies. But so far little truly integrated research on human–nature systems has been found [19]. Research methods dominated by Newtonian approaches have played a key role in the study of global environmental issues. How can we integrate the contingency and self-organisation of Darwinism and the relativity and specificity of social research with the Newtonian view aiming for universality and predictability?

A variety of approaches are now emerging to integrate disciplinary practices across these different traditions [20••]. Triangulation is being developed as a concept which can be used to link methods and datasets of quantitative and qualitative, and the context–mechanism–outcome configuration developed by Pawson and Tilley [21] is another research paradigm combining quantitative and qualitative approaches [3]. We argue that scientists operating in the social domain and the natural domain both need to increase the range of practices based on these approaches to bridge the disciplinary divide and “construct” this bridge to bear diverse traffic from both ends.

In addition, as Wimmer et al summarized, tool transfer, model migration, methodological analogies, and metaphor transfer are the four modes of interdisciplinary methodology learning [22]. In the development of methodologies for integrating the societal processes, ecological processes and physical processes for understanding global environmental change, we believe that borrowing and learning from other more fundamental sciences like physics and mathematics is a valuable approach. For example, traditional hydrology is a Newtonian discipline, while recently developed eco-hydrology extends to understand linkages between hydrologic and vegetation dynamics, introducing the Darwinian principles of competition and survival into hydrological models [23], typically resulting in a shift from relatively simple to complex system dynamics. As the system dynamics become more complex, the predictability objective typically shifts from one concerned more with specific patterns in space and time to one concerned more with the characteristics of the variation in the systems (e.g. its climatology). As there is considerable similarity between the emerging socio-hydrology and eco-hydrology disciplines [24-28], the development of socio-hydrology has learnt a lot from the success of eco-hydrology.

The grand challenge of integrating societal processes with bio-physical processes represented in endeavours such as ecological and hydrological process modelling is that social science, which traditionally uses unstructured data and adopts a “thick descriptive” approach, is good at description but poor at prediction [29]. This is why the key findings from social science have hardly been used in natural resources management, which is dominated by natural scientists and engineers [12••]. We argue that the social sciences need to make useful generalizations and aim for quantification in this context [4]. Recently, computational social science has been developing the capacity to collect and analyze large, heterogeneous, data sets [30]. This may be a promising starting point to look for regularities in sociological phenomena, though there is a trap in thinking that such analyses present ‘truths’ about social realities rather than presenting patterns for further inquiry, interpretation and change. Societal processes that are amenable to measurement and quantification, makes it easier to integrate them with other natural processes in models [8].

DEVELOP system-scale experimental research

We propose developing empirically-based, system-scale, experimental research as a starting point for establishing the new methodological paradigm discussed above. This is because very limited research integrating these disciplinary advances has been conducted on any co-evolutionary coupled human-nature system (e.g. a catchment) [31]. We firstly propose a “paired system” approach. We borrow this concept from control-intervention experimental methods such as the “paired catchment” approach in hydrology [32]. In this approach, two small catchments ideally of “identical” size, shape, and land-use are selected. Rainfall and streamflow are measured for a sufficiently long timeframe at both the control and intervention (treatment) catchments, then the hydrologic responses to rain and other inputs are calibrated between the catchments. When a satisfactory “calibration” is established, a change is imposed on the treatment catchment. The calibrated relationship is applied to estimate the expected response in the treatment catchment in the absence of the change, and the expected and observed responses are then compared to find the impact of the change. Multiple case catchments are an extension of this concept.

This is a good methodological example that could be incorporated for developing system-scale experimental research on co-evolutionary coupled human-nature systems. We may choose several small systems, ideally with “identical” societal, ecological and physical patterns and scales as the experimental paired systems. As we could not “control” and “treat” any real human-nature system in the experiment, instead, we use the real processes of evolution of these selected systems as the control or treatment depending on the perspectives of the analysis. To analyses the different systems, a historical trend analysis method could be used to describe these real processes. Following that, mechanisms to analyse the two-way feedbacks (and lags) between the societal sub-system and natural sub-system of each selected system could be determined so as to explain these co-evolutionary processes. This would involve identifying/describing initial conditions, tipping points, bifurcations, resilience within a state, multiple-stable states, and path-dependence underlying each selected co-evolving human-nature system. The mechanisms could cover laws, or theory as narrative; at least theory as enlightenment. Based on the mechanisms, the similarities and differences between these systems across societal, economic, ecological and physical (e.g. climatic) gradients would be determined [33,34•]. The phases of human disturbance of the natural sub-system from one selected system, e.g. characterized as early civilization, rapid economic development, serious environmental degradation and rebalance between humans and the environment, could be used to enlighten future trajectories of the other selected systems.

Concurrently we propose another system-scale experiment using interdisciplinary systems modelling in the laboratory. Scientific advances in machine learning, artificial intelligence, game and control theory, agent-based modelling, virtual reality and complex systems theory have enabled data-driven modelling of the adaptive human-nature system [35]. With this systems modelling, the system-scale experiment on the human-nature interactions could be conducted repeatedly, which could provide another empirical approach to strengthen the understanding of the complex and adaptive human-nature relationship and make it more predictable or projectable [35]. Another approach we propose is governing experiments carried out in real time with the aid of systems learning/innovation labs, i.e., situated in the overall orange circle in Figure 1, which can address the two lags in observation, explanation and societal action which we mentioned above. The systems learning/innovation labs is an emerging design trajectory in theory and practice characterised by knowledge co-creation [36]. The combined use of empirically based system-scale experimental research approaches, with ‘co-design’ innovation labs or units, hold promising possibilities to better understand, model, forecast, and manage the co-evolutionary human-nature system in which we live.

Our understanding of the human-nature relationship lags our need to manage it. This is a significant cause of global environment degradation. Globally, there are several large research programs addressing the system-scale understanding of coupled human-nature systems. The Heihe Hydrology-Ecology-Economy Integration program, an 8-year (2010-2018) program funded by the Natural Science Foundation of China is a good example which aims to advance catchment hydrology by developing an inter-disciplinary understanding, together with integrated modelling of the systemic relations between hydrology, ecology and economy in catchments. Broad international research collaboration among these big programs should be developed to help cross fertilization. Meta-syntheses of knowledge findings from these programs will contribute to a new methodological paradigm for understanding the adaptive human-nature relationship. This requires deepened and broadened commitments and collaboration of scholars and practitioners. The outcomes from these commitments and collaborations will, we hope, contribute to a future version of this journal dedicated to “*System Dynamics and Sustainability*”.

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